THE FUTURE OF LOW RANK COAL UPGRADING

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INTRODUCTION

The Advanced Coal Conversion Process (ACCP) being demonstrated in Colstrip, Montana consists of thermal processing coupled with physical cleaning to upgrade high-moisture, low-rank coals, giving a fuel with improved heating value and low sulfur content.

The process and product, patented as SynCoal®, has been developed by the Rosebud SynCoal Partnership (RSCP) as part of Round I of the U.S. Department of Energy's Clean Coal Technology Program. RSCP is a general partnership formed in December 1990 for the purpose of conducting the demonstration and commercializing of the ACCP technology. Western SynCoal Company (WSC), a subsidiary of Montana Power Company's Energy Supply Division, is the managing general partner.

WSC owns the technology and has exclusively licensed it to the partnership. The partnership manages the demonstration project and all activities related to commercialization. DOE has contributed about $43 million (41%) to the $105 million demonstration project, with the remainder provided by RSCP.

The plant is located adjacent to the unit train loadout facility within Western Energy Company's Rosebud Mine near Colstrip, Montana. The production unit, having a capacity of 1,000 tons per day of upgraded coal, is one-tenth the size of a commercial facility and benefits from the existing mine and community infrastructure.

TECHNOLOGY OVERVIEW

The SynCoal® process enhances low-rank subbituminous and lignite coals by a combination of thermal processing and physical cleaning. The process consists of three major steps: thermal treatment in an inert atmosphere, inert gas cooling of the hot coal, and pneumatic cleaning. The results are a reduction in moisture content from 25-40% in the feedstock to as low as 1% in the product, concurrently increasing heating value from 5,500 – 9,000 Btu/lb to as high as 12,000 Btu. At the same time, sulfur content is reduced from a range of 0.5 – 1.5% to as low as 0.3%. Each ton of raw Rosebud subbituminous coal produces about 2/3 ton of SynCoal®.

Raw coal from the Rosebud mine unit train stockpile is screened and fed to a vibratory fluidized-bed reactor, where surface water is removed by heating with hot combustion gas. Coal exits this reactor at a temperature slightly higher than that required to evaporate water and is further heated to nearly 600°F in a second vibratory reactor. This temperature is sufficient to remove chemically bound water, carboxyl groups, and volatile sulfur compounds. In addition, a small amount of tar is released, partially sealing the dried product. Particle shrinkage causes fracturing, destroys moisture reaction sites, and liberates the ash-creating mineral matter.

The coal then is cooled to less than 150°F by contact with an inert gas (carbon dioxide and nitrogen at less than 100°F) in a vibrating fluidized-bed cooler. Finally, the cooled coal is fed to deep bed stratifiers where air pressure and vibration separate mineral matter from the coal including the pyrite-rich ash, thereby reducing the sulfur content of the product. The low specific gravity fractions are sent to a product conveyor while heavier fractions go to fluidized bed separators for additional ash removal.

The fines handling system consolidates the coal fines that are produced in the conversion, cleaning and material handling systems. The fines are gathered by screw conveyors and transported by drag conveyors to a bulk cooling system. The cooled fines are blended with the coarse product or stored in a 250-ton capacity bin until loaded into pneumatic trucks for off-site sales. When sales lag production, the fines are slurried with water in a specially designed tank and returned to the mine pit.

PROJECT HISTORY

The Cooperative Agreement with DOE for the ACCP demonstration facility was signed in September 1990. Initial operations began in April 1992, with the first 24-hour run occurring in May 1992 and the first significant shipments in June. Several material handling problems were encountered during initial operations that required extensive modifications and hampered the efforts to address the product issues of dustiness and spontaneous heating. Parallel efforts to correct the material handling shortfalls and investigate treatments to mitigate the product issues were pursued until August 1993, when the demonstration facility reached full production capability. Efforts have continued since to establish test customers and address the product handling issues for safe and reliable transportation and handling. Three different feedstocks were trucked to and tested at the facility in 1993 and early 1994. In 1994, several test burn programs were conducted in both utility and industrial applications and three regular customers were established. The demonstration facility start focused increasing amounts of attention on process improvements and operating cost reductions. Since 1995, an additional focus has been the development of commercial markets.

Through June 1997, 1.6 million tons of raw coal have been processed and over 1 million tons of SynCoal® has been produced. Total shipments of SynCoal® products have exceeded 950,000 tons. The plant has consistently operated at over 100% of its design capacity and at its target 75% availability. The demonstration facility is expected to operate through June 1998 under the Cooperative Agreement.

LESSONS LEARNED

MECHANICAL RELIABILITY

Initial operations of the demonstration plant discovered numerous weak links and bottlenecks. The rotary airlocks between process reactors were under powered and jammed tripping the entire plant. The fines gathering and conveying system was severely undersized and wore out rapidly. As operations continued, problems with fan bearings, conveyors and particularly the vibrating reactor vessels were uncovered. Generally all of these problems have been solved or mitigated by improved design and repair or replacement. These lessons can be carried forward to the next generation plant design.

PRODUCT ISSUES

The project team has worked continuously to improve the process and product since the initial startup identified the dustiness and spontaneous combustion issues. Additionally, as with any first-of-a-kind plant, significant efforts have been directed toward improving process efficiencies and reducing overall costs. A CO_2 inerting system was added to prevent self heating in the storage areas and enhance the product stability in transit to customers. After verifying the effectiveness of this system, an additional inert gas process was added to reduce the gas expenses and further test the impact on product stability.

A wide variety of additives and application techniques were tested in an effort to reduce dustiness and spontaneous combustion. A commercial anionic polymer applied in a dilute concentration with water was found to provide effective dust control and is environmentally acceptable. A companion product was identified that can be used as a rail car topping agent to reduce wind losses. The application of the dilute water based suppressant, which is known as dust and stability enhancement (DSE), also provided a temporary heat sink, helping control spontaneous combustion for short duration shipments and stockpile storage. This work led to extensive investigation of stockpile management and blending techniques.

After adapting these lessons, safe and effective techniques for blending SynCoal® with raw coal, petroleum coke, and SynCoal® fines and handling the resultant products have evolved. This work further led to the development of stabilization process concepts (patents pending) which were successfully piloted at a 1,000 lb/hr scale. A plant modification was designed, but has not been installed due to the high retrofit costs. The next generation plant is expected to incorporate the stabilization process technology.

ENVIRONMENTAL PERFORMANCE

It was originally assumed that SO_2 emissions would have to be controlled by injecting chemical sorbents into the ductwork. However, a mass spectrometer installed to monitor emissions and performance testing, discovered that the process configuration inherently limits the gaseous sulfur production, eliminating the need for chemical sorbent injection. The sorbent injection system remains in place should a higher sulfur coal be processed.

Fugitive dust from material handling and coal cleaning operations throughout the plant is controlled by negative pressure dust collection hoods located at all transfer points and other dust emission sources. High efficiency baghouses are connected to the dust collection hoods. These baghouses have been effective, as demonstrated by stack tests on the east and west baghouse outlet ducts and the first-stage drying gas baghouse stack in 1993. Emission rates are well within the limits specified in the air quality permit, at 0.0013 grains/dry standard cubic feet (gr/dscf) for the baghouse outlet ducts and 0.0027 gr/dscf for the drying gas baghouse stack. Another stack survey conducted in May 1994 verified that emissions of particulates, SO_2, oxides of nitrogen (NO_x), carbon monoxide (CO), total hydrocarbons, and hydrogen sulfide (H_2S) from the process stack are within permitted levels.

Through June 1997, the demonstration operations have been cited for only five minor violations as a result of MSHA's regular inspections. It was noted at the celebration of 1 million tons of production that the operating work force had completed over 300,000 manhours without a lost time accident.

PRODUCT APPLICATIONS

Utility Applications

A SynCoal® testburn was conducted at the 160 MW J.E. Corette plant in Billings, Montana. A total of 204,000 tons of SynCoal® was burned between mid-1992 and April 1996. The testing involved both handling and combustion of DSE treated SynCoal® in a variety of blends. These blends ranged from approximately 15% to 85% SynCoal® with raw coal. Overall, the results indicate that a 50% SynCoal®/raw coal blend provides improved performance, with SO_2 emissions reduced by 21% at normal operating loads, and no noticeable impact on NO_x emissions.

In addition, the use of SynCoal® permitted deslagging the boiler at full load, thereby eliminating costly ash shedding operations. This also provided reduced gas flow resistance in the boiler and convection passage, thereby reducing fan horsepower and improving heat transfer in the boiler area, resulting in an increase in net power generation of about 3 MW.

Deliveries of SynCoal® are now being sent to Colstrip Units 1 & 2 in Colstrip, Montana. Testing has begun on the use of SynCoal® in these twin 320-MW pulverized coal fired plants. The results of these tests will provide information on boiler efficiency, power output, and air emissions. A total of 158,000 tons have been consumed to date. A new SynCoal® delivery system is being designed which, if installed, would provide selectively controlled pneumatic delivery of fuel to individual pulverizers in the two units. This system would allow controlled tests, providing valuable comparative data on emissions, performance and slagging.

Alternative Coal Testing

In May 1993, 190 tons of Center, North Dakota lignite were processed at the ACCP demonstration facility, producing a 10,740 Btu/lb product, with 47% reduction in sulfur and 7% reduction in ash. In September 1993, a second test was performed processing 532 tons of lignite, producing a 10,567 Btu/lb product with 48% sulfur reduction and 27% ash reduction. The Center lignite before beneficiation had 36% moisture, about 6,800 Btu/lb, and about 3.0 lb of SO_2/million Btu.

Approximately 190 tons of these upgraded products were burned in the Milton R. Young Power Station Unit #1, located near Center. This initial test showed dramatic improvement in cyclone combustion, improved slag tapping, and a 13% reduction in boiler air flow, reducing the auxiliary power loads on the forced draft and induced draft fans. In addition, the boiler efficiency increased from 82% to over 86% and the total gross heat rate improved by 123 Btu/kWh.

Similar test programs were also conducted on 290 tons of Knife River lignite from North Dakota and 681 tons of Amax subbituminous coal from Wyoming producing 10,670 Btu/lb and 11,700 Btu/lb products respectively.

Industry Applications

Several industrial cement and lime plants have been customers of SynCoal® for an extended period of time. A total of about 190,000 tons have been delivered to these customers since 1993. They have found that SynCoal® improves both capacity and product quality in their direct fired kiln applications, because the steady flame produced by SynCoal® appears to allow tighter process control and improved process optimization.

A bentonite producer has been using SynCoal® as an additive in greensand molding product for use in the foundry industry, having purchased about 37,500 tons. They have found SynCoal® to be a very consistent product, allowing their greensand binder customers to reduce the quantity of additives used and improving the quality of the metal castings produced.

SIGNIFICANCE OF THE TECHNOLOGY

SUPPLEMENTAL FUEL IMPACTS

The utility segment is the largest and most established market for all domestic coal sales. Since the ACCP is by its nature a value added process and the product has been determined to require special handling, unique situations must be identified where the addition of SynCoal® to the firing mix provides sufficient benefit to more than offset the increased delivered cost compared to raw western coal. These requirements have led RSCP to focus on marketing the product as a supplemental fuel in utility applications and then only to units that have specific problems with slagging or flame stability.

Utility plants with design or fuel related limitations such as the J.E. Corette station and Colstrip Units 1 & 2 can benefit from decreased slagging, reduced SO_2 emissions, improved net generation, and reduced heat rate by burning a controlled amount of SynCoal® selectively injected into the boiler.

INDUSTRIAL FUEL OPPORTUNITIES

The industrial market segment is much more amenable to special handling since these customers normally receive much small quantities and are much more sensitive to fuel quality issues. RSCP has developed a technique of shipments in covered hopper rail cars and/or pneumatic trucks that allows long haul distances and, when combined with inerted bin storage, provides safe and efficient handling.

SynCoal® has been found to provide superior performance in direct fired applications particularly as a blend with petroleum coke. SynCoal® provides good ignition and stable flame characteristics while the petroleum coke is low cost and requires a longer burning time, expanding the processing zone. This blend of characteristics has provided a significant advantage to SynCoal®'s cement and quicklime customers. Additionally, recent tests of SynCoal®/petroleum coke blends have shown improved handling characteristics with regard to dustiness and self heating.

SynCoal® produces a gas-like flame when burned alone. In some direct fired applications (such as road paving asphalt plants), it can be a much lower cost option that propane, providing a small but valuable market.

METALLURGICAL PROCESS OPPORTUNITIES

SynCoal®'s consistent characteristics and high volatile matter and carbon contents make it a good reducing agent for some metallurgical processing applications. Since low moisture content is a key characteristic for this segment, the covered hopper rail car and/or pneumatic truck delivery system is readily accepted. SynCoal® has been used successfully in ductile iron metal casting applications as a greensand binder additive due to these characteristics. RSCP has been working with a metallurgical silica producer to determine if SynCoal® is viable in their application. RSCP is continuing to pursue alternative markets in various metallurgical reduction applications and SynCoal® may even be a viable substitute for natural gas used to reduce metallurgical coke use in blast furnaces.

UNCERTAIN FUTURE

TECHNOLOGY DEVELOPMENT NEEDS

Additional development is required to improve two major product characteristics: spontaneous combustion and dusting. In addition, further market development and customer education are needed to position SynCoal in the proper market niches and overcome natural resistance to a new product.

The upgraded coal produced to date has exhibited spontaneous heating and combustion. When a coal pile (more than 1 to 2 tons) is exposed to any significant airflow for periods ranging from 18 to 72 hours, the coal reaches temperatures at which spontaneous combustion or autoignition occurs. Spontaneous heating of run-of-mine, low-rank coals has been a common problem but usually occurs after open air exposure periods of days or weeks, not hours. However, dried, low-rank coals have universally displayed spontaneous heating tendencies to a greater degree than raw, low-rank coals.

The product is basically dust free when it exits the processing facility due to numerous steps where the coal is fluidized in process gas or air, which removes the dust-size particles. However, typical of all coal handling systems, each transfer of the product coal after it leaves the process degrades the coal size and produces some dust. Because the SynCoal® product is dry, it does not have any inherent ability to trap small particles on the coal surfaces. This allows any dust-size particles that are generated by handling to be released and become fugitive.

In January 1995, a cooperative research project was initiated to determine the effects of different processing environments and treatments on low-rank coal composition and structure. Specific objectives are (1) to study the explosivity and flammability limits of dust from the process and (2) to identify the causes of spontaneous heating of upgraded coals. Other participants in this study are the Amax Coal Company and EnCoal, who have also experienced similar effects with their upgraded products.

COMPETITIVE IMPACTS

Due to the handling issues, RSCP has taken a three-pronged approach to satisfying customer needs for a safe, effective way to handle SynCoal®. The first method is to employ DSE treatment, which allows conventional bulk handling for a short period (about one week) but does degrade the product heat content. The product eventually becomes dusty and susceptible to spontaneous heating again.

The second technique uses contained storage and transportation systems with pneumatic or minimal exposure material handling system. This technique provides maximum product quality and actually enhances the material handling performance for many industrial customers; however, transportation requires enclosed equipment and is impractical for the bulk coal handling systems of large utility customers.

The third approach is to develop a stabilization process step. SynCoal's previous work has been of great benefit in the collaborative research with EnCoal. SynCoal hopes to incorporate its stabilization process in the next generation facility or develop a smaller pilot operation in direct response to a specific customer requirement.

These approaches should allow SynCoal® to be tested in some more novel applications such as blast furnace injection systems and electric arc furnace reducing agents.

CONCLUSION

Rosebud SynCoal has developed an advanced coal conversion process which has the potential to enhance the utility and industrial use of low-rank western subbituminous and lignite coals. Many of the power plants located throughout the upper Midwest have cyclone boilers, which burn low ash fusion temperature coals. Presently, most of these plants burn Illinois Basin high-sulfur coal. SynCoal® is an ideal supplemental fuel for these and other plants because it allows a wider range of low-sulfur raw coals to be used to meet more restrictive world-wide emissions guidelines without derating of the units or the addition of costly flue gas desulfurization systems.

The ACCP has potential to convert inexpensive low-sulfur, low-rank coals into valuable carbon-based reducing agents for many metallurgical applications, further helping reduce worldwide emissions and decrease the U.S. dependence on foreign energy sources.

The ACCP produces a fuel which has a consistently low moisture content, low sulfur content, high heating value, and high volatile content. Because of these characteristics SynCoal® could have significant impact on SO_2 reduction and provide a clean, economical alternative fuel to many regional industrial facilities and small utility plants allowing them to remain competitively in operation.